P1.7

Sampling Errors of Monthly-mean Radiative Fluxes from the Earth Radiation Budget Satellite

T. Dale Bess[1] and Takmeng Wong
Atmospheric Sciences Division, Langley Research Center, NASA
Hampton, Virginia 23681

G. Louis Smith
Virginia Polytechnic Institute and State University
Langley Research Center. NASA. Hampton, Virginia 23681

1. Introduction

The Earth Radiation Experiment (ERBE) consisted of scanning and nonscanning radiometers on the dedicated Earth Radiation Budget Satellite (ERBS) and also on the NOAA-9 and -10 operational spacecraft (Barkstrom and Smith, 1986). The non-scanning radiometers included a pair of wide field-of-view (WFOV) radiometers for measuring outgoing longwave radiation and reflected solar radiation (Luther et al., 1986). The ERBS was placed into an orbit with 57° inclination and 620 km altitude on 16 October 1984. The instruments began collecting data in November 1984 and the non-scanning radiometers provided data until June 2002, providing a 17-year data set (Bush et al., 2002 a&b).

An intercomparison of ERBS data with ScaRaB data (Kandel et al., 1994, 1995), found large differences in monthly-mean radiative fluxes between ERBS and ScaRaB results in a few regions (Bess et al., 1999). These differences were traced to inadequate temporal sampling by the ERBS nonscanning radiometers. Consequently, algorithms were developed for computing the temporal sampling error of the monthly-mean radiation outgoing longwave and reflected shortwave fluxes computed from the ERBS WFOV (Smith, 1997, 1998). These algorithms were tested on a limited data set (Spangenberg et al., 1999) and now have been applied to the ERBS data set. This paper presents the results of the temporal sampling algorithm for the full data period. The data set includes monthly means of outgoing longwave and reflected solar radiation on a 10° geographical grid computed by use of the traditional shape factor method and on a 5° grid by use of a numerical filter to enhance the resolution of the WFOV measurements (Smith et al., 1986). Only the 5° OLR data product is considered in this paper.

[1]Corresponding author address: T. Dale Bess, Mail Stop 420, Langley Research Centre, NASA, Hampton, VA 23681.
e-mail: t.d.bess@larc.nasa.gov

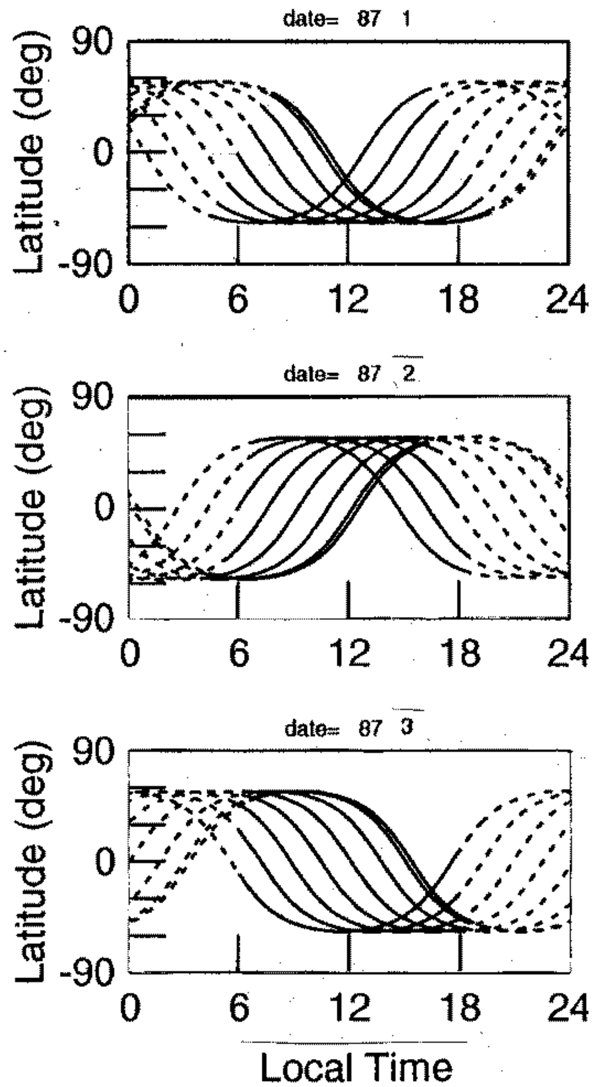
2. Temporal Sampling and Averaging

The inclination of the ERBS orbit was selected such that the spacecraft precesses through all local times in a 72-day period (Harrison et al., 1983). From these measurements, the daily average and monthly averages are computed (Brooks et al., 1986). Over land there is a diurnal cycle of OLR which resembles a half-sine wave (Minnis et al., 1984). The computation of monthly-mean OLR incorporates this half-sine variation over land. Over ocean the diurnal cycle is much weaker and a simple average is used. These monthly-means are archived on S-4 data products, which are available from the Atmospheric Sciences Data Center of Langley Research Center via the web at http://eosweb.larc.nasa.gov

Figure 1 shows the coverage of local time for a given latitude for the ERBS for January, February and March of 1987. Figure 2 shows how equator-crossing time for January and July changes as a function of year. In each panel, the orbit at the first of the month is indicated by a heavy line. The night-time portion of the orbit is indicated by a dotted line. During the month the orbit precesses to an earlier local time. For January, the northern-most zone is not well-observed during day and the southern-most zone is not well-observed during night. In March, there are observations during day and night for all latitudes. In order to account for the diurnal variation, measurements are necessary during both day and night over land. If both day and night measurements are not available for a

month for a land region, the monthly-mean OLR is not computed and a fill value is placed in the data product. We denote these cases as Type I rejects.

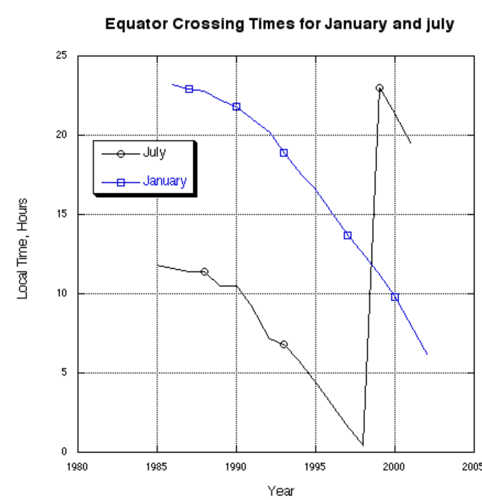
Figure 1. Sampling of local times for ERBS Spacecraft.



Not accounting for the diurnal variation over land can result in large errors of computed daily means of OLR. As the spacecraft precesses, for some orbits the temporal sampling also can result in errors which can be quite large due to the inclusion of the half-wave cycle in the computation. Smith (1997) gave an equation for calculating the standard deviation of the temporal sampling error of the monthly-mean OLR, applicable to land or ocean. This error, which we will denote simply as time sampling error, is due to the method of computation, the time at which each of the measurements were taken, the time variability and autocorrelation of the OLR field and the deviation of the diurnal cycle of the region from the half-sine fit.

Due to the orbit precession and the concomitant vagaries of sampling of gridded regions, the time sampling error varies greatly and thus is computed for each region for each month. If the time sampling error exceeds 12 W-m^{-2}, the monthly-mean value is deemed useless for climate studies and is replaced by a fill value on the S-4 product. We denote these cases as Type II rejects. Figure 3 shows Type I and Type II rejects for January and July.

Figure 2. Equator-crossing time as afunction Of year for January and July.



3. Results

Figure 4 is a map showing the time sampling errors for OLR for January 1985. Because a 5^{o} grid is used and the spacecraft was in a 57^{o} inclination orbit, the map covers 60^{o}S to 60^{o}N, which consists of 1728 5^{o}x5^{o} regions. Poleward of 60^{o} latitude there are no measurements. At the southern tip of South America are 2 regions for which no night-time measurements were available. These 2 cases are Type I rejects. There is a zone between 45^{o} N and 55^{o}N with regions where several time-sampling errors exceed 12 W-m^{-2}, i.e. these are Type II rejects. The irregular longitudinal spacing of these

reject regions is due to the discretizaton of the grid system together with the orbit precession, which results in a chaotic distribution of measurements across a given latitude zone. There is another zone of regions with time sampling errors greater than 12 W-m^{-2} between 20^{o}S and 35^{o}S, due to a paucity of night-time measurements. With only a few night-time measurements, the “floor” from which the half-sine is measured is not accurately determined, so that the daily average has large error. The pattern of time sampling errors is similar for the Januaries of 1985 through 1988, after which the northern zones have far fewer regions with large time sampling errors.

Figure 5 is a map of time sampling errors for OLR for July 1985. The northern-most zones have a number of Type I reject regions, due to lack of night-time measurements. There is also a zone between 25^{o}N and 35^{o}N of regions with large time sampling errors, resulting in Type II rejects.

Figure 6 shows the relative frequency of time sampling errors for January and July, averaged over the 17-year data period. Most regions have time sampling errors less than 3 W-m^{-2} and the fraction with greater than 8 W-m^{-2} is minuscule.

4. Concluding Remarks

This study has examined the OLR from the numerical filter data product. Future work should investigate the time sampling errors of the reflected shortwave data product for the 5^{o} numerical filter and the time sampling errors for the shape factor data product, which is for 10^{o} regions, for both the OLR and reflected shortwave radiation.

Acknowledgments: This work was supported by the Earth Science Enterprise of NASA. GLS was supported through Langley Research Center by cooperative agreement with Virginia Polytechnic Institute and State University. Data were provided by the Atmospheric Sciences Data Centre of Langley Research Centre.

REFERENCES

Barkstrom, B.R. and G.L. Smith, 1986: The Earth Radiation Budget Experiment: Science and Implementation, *Rev. of Geophys., 24*, 379-390.

Brooks, D.R., E.F. Harrison, P. Minnis, J.T. Suttles and R.S. Kandel, 1986: Development of algorithms for understanding the temporal and spatial variability of Earth radiation balance, *Rev. Geophys., 24*, 422-438.

Bess, T. D., G. L. Smith, K. A. Bush and D. A. Rutan: “Intercomparison of ScaRaB and ERBS monthly mean radiation fluxes,” 60-63, *Proc. 10th Conf. Atmos. Rad.*, American Met. Soc., Madison, Wisc. June 1999.

Bush, K.A., G.L. Smith, R.B. Lee and D.F. Young, 2002: The Earth Radiation Budget Satellite 15- year data set, *SPIE Proc. vol. 4882*. EUROPTO.

Bush, K.A., G.L. Smith, R.B. Lee, III, T-M. Wong and D.F. Young, 2002: The Earth Radiation Budget 15-year data set, *Proc. 11-th Conf. Atmos. Rad*.

Harrison, E. F., P. Minnis, and G. G. Gibson, 1983: Orbital and cloud cover sampling analyses for multi-satellite Earth radiation budget experiments, *J. Spacecraft & Rockets, 20*, 491-495.

Kandell, R. S., J. L. Monge, M. Viollier, L.A. Pakho mov, V. I. Adasko, R. G. Reitenbach and E.H. Raschke, 1994: The SCARAB Project: Earth Radiation Budget observations from the METEOR satellites, *Adv. Space Res., 14,* 147- 154.

Kandel, R., M. Viollier, L. A. Pakhomov, V. A. Golovko, E. Raschke, R. Stuhlmann, and the international ScaRaB Scientific Working Group (ISSWG), 1998: The ScaRaB Earth radiation budget data set, *Bull. Amer. Met. Soc., 78,* 765-783.

Lee, R.B.,III, J. Paden, D.K. Pandey, R.S. Wilson, K.A. Bush and G.L. Smith, 2002: On-orbit calibrations of the ERBE active cavity radiometers on the ERBS, *Proc. SPIE 4814-53*.

Luther, M. R., J. E. Cooper and G. R. Taylor, 1986: The Earth Radiation Budget Experiment non-scanning instrument, *Rev. of Geophys., 24*, 391-399.

Minnis, Patrick and Harrison, Edwin F., 1984: Diurnal Variability of Regional Cloud and Clear Sky Radiative Parameters Derived from GOES Data; Part III: November 1978 Radiative Parameters. *J. Climate Appl. Meteorol., 23*, 1032-1051.

Smith, G. L., 1997: Time-Sampling Errors of Outgoing Longwave Radiation from Satellites, *Proc. 9-th Conf. Atmos Rad*.

Smith, G. L., 1998: “Time-Sampling Errors of Albedo from Satellites.”*Proc. 14-th Conf. Prob. and Stat. in Atmos. Sci*.

Smith, G. L., R. N. Green, E. Raschke, L. M. Avis, J. T. Suttles, B. A. Wielicki and R. Davies, 1986: Inversion methods for satellite studies of the Earth's radiation budget: Development of algorithms for the ERBE mission, *Rev. Geophys, 24*, 407-421.

Spangenberg, D. A., G. L. Smith and D. F. Young, 1999: "Temporal Sampling Errors of Monthly Mean Data Products from the Earth Radiation Budget Satellite Nonscanning Radiometers," 219-222, *Proc. Third Symp. Integrated Observing Systems*.

Figure 3. Type I and Type II rejects for January and July.

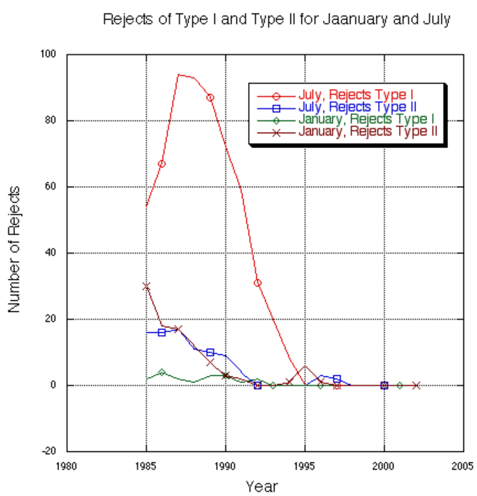


Figure 5. – Map showing time sampling errors for OLR for July 1985.

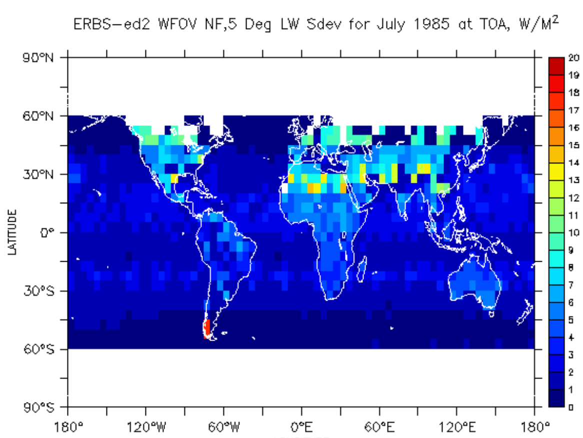


Figure 4. – Map showing time sampling errors for OLR for January 1985.

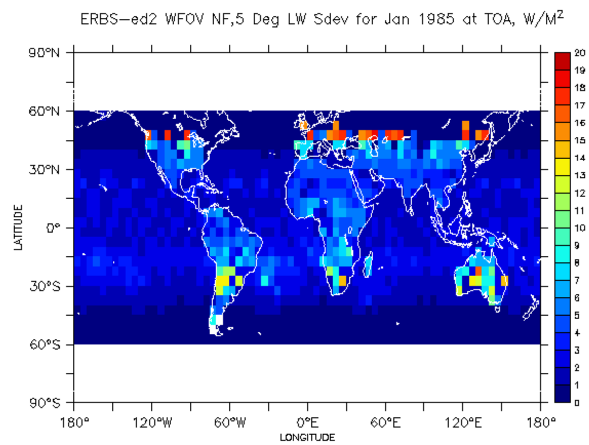


Figure 6. – Relative frequency of time sampling errors for January and July, averaged over 17-year period.